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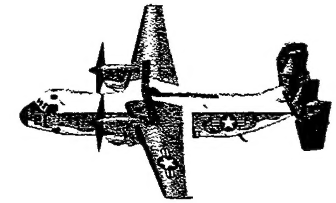
V_{MCA} Flight Test of the C-2A

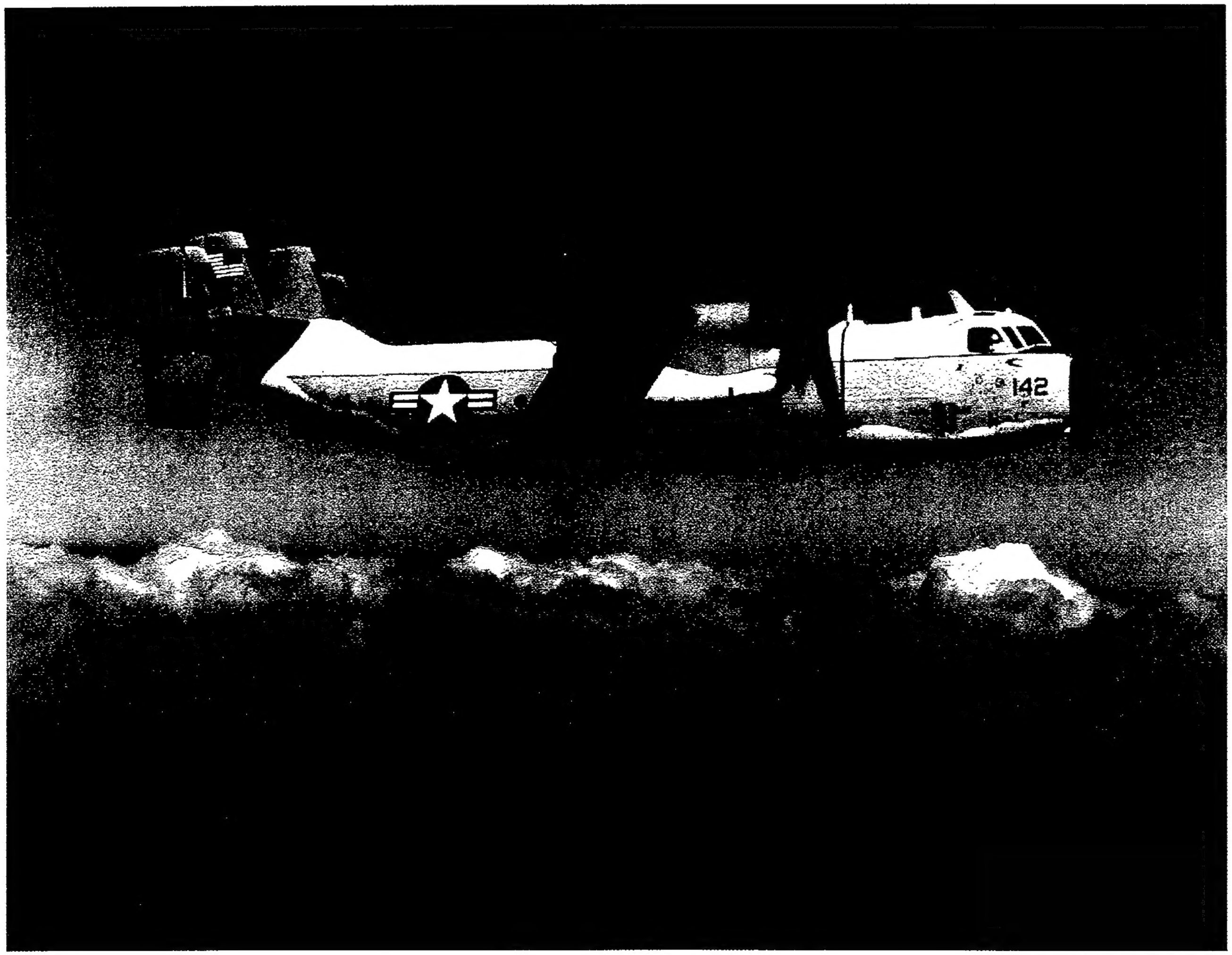


Michael J. Wagner
Charles E. Webb
Naval Air Warfare Center-Aircraft Division
Patuxent River, MD

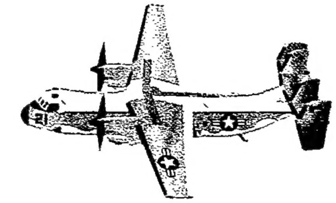
30 Mar 2001

VMC 3_5_2001

NAVAL AVIATION SYSTEMS TEAM

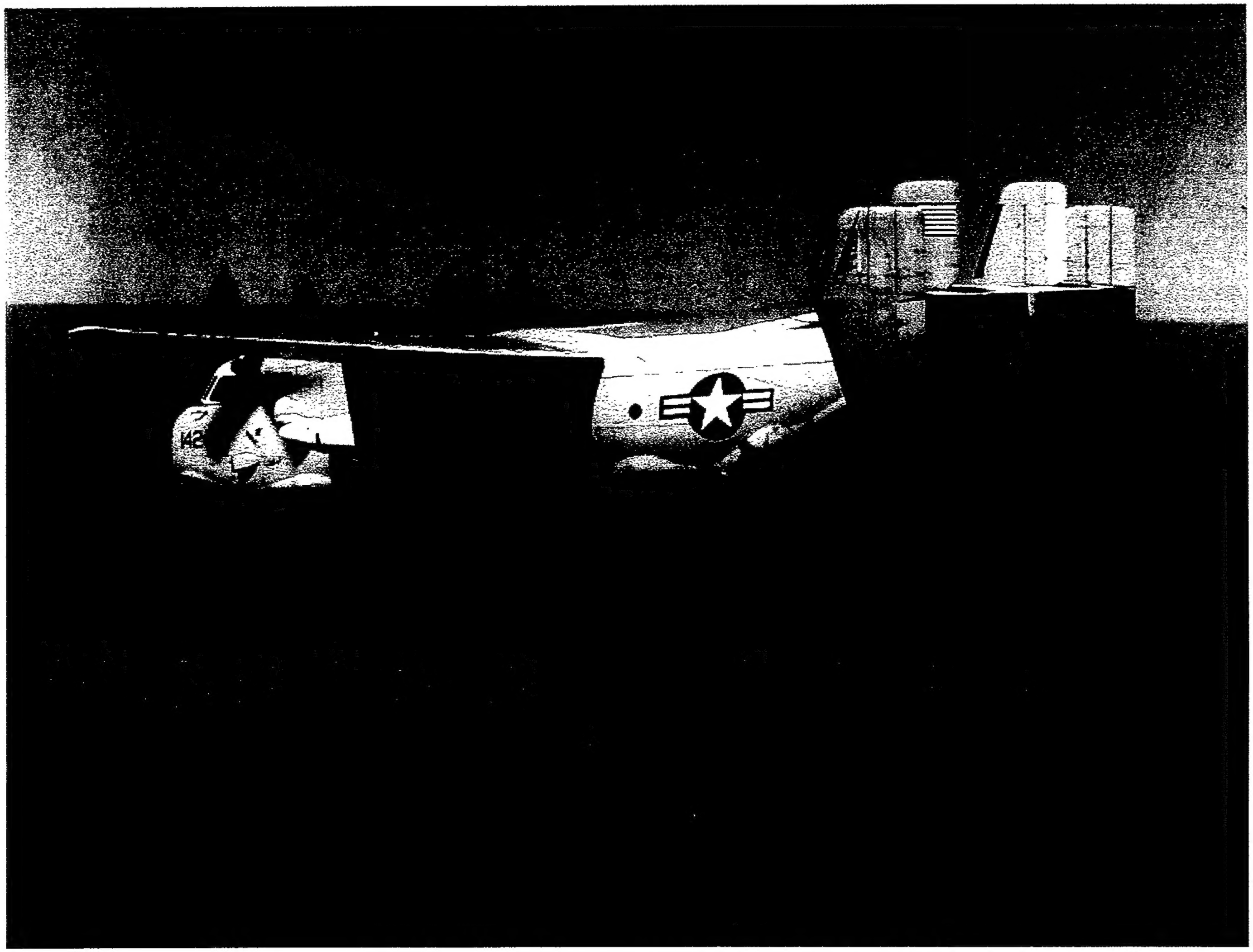


C-2A Greyhound - The Basics

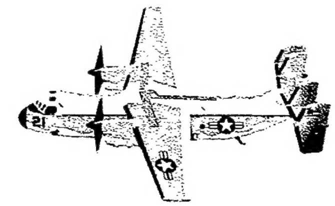


- Aircraft Carrier-based cargo aircraft built by Grumman. Original design/construction early-mid 60's.
- Twin-engine turboprop producing 4,600 SHP per engine.
- Range - 1200 NM, Basic weight - 38,000 lbs., Max T/O weight - 60,000 lbs.
- Cargo - 10,000 lbs., Pax - 26
- Wingspan - 81 feet, Length - 57 feet

NAVAL AVIATION SYSTEMS TEAM

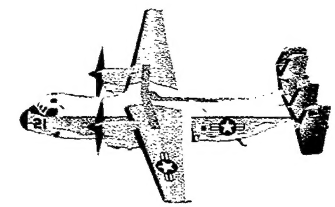


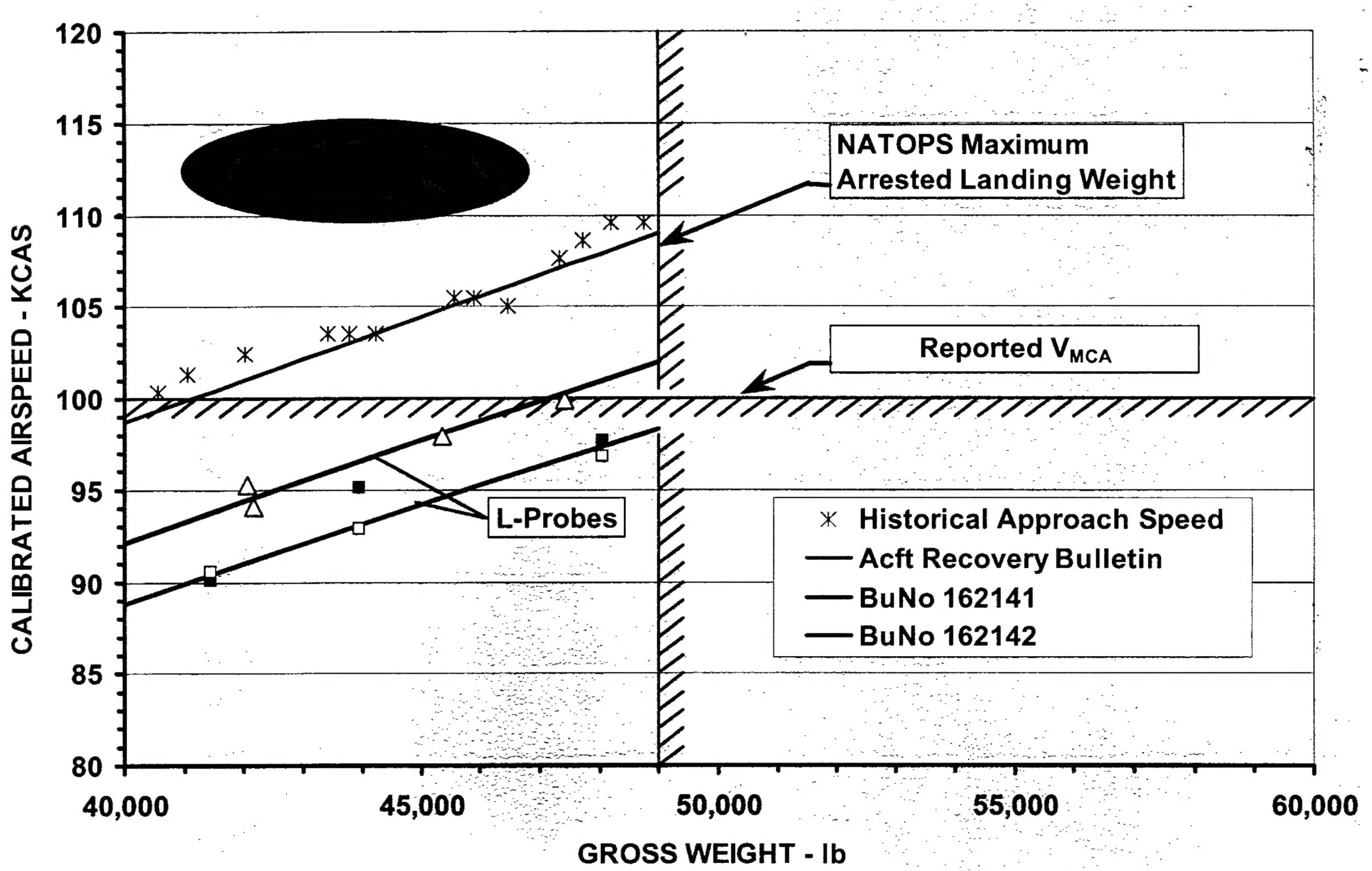
V_{MCA} - Background



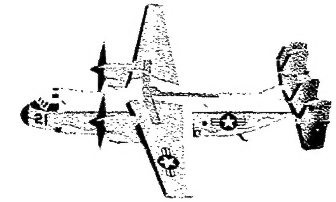
- Original pitot-static system upgraded to L-shaped pitot-static probes
- L-Probe test results showed approach speeds below some historical approach speeds and those published in Aircraft Recovery Bulletin.
- Approach speeds also below then-published V_{MCA} for nearly all landing weights.

Configuration PA(20) Approach Speeds





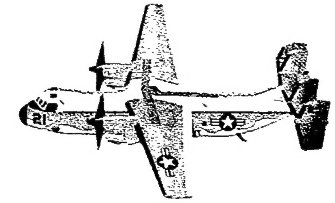
Force Aircraft Test Squadron



V_{MCA} - Background (2)

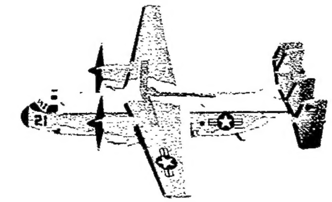
- Then-current Flight Manual (NATOPS) V_{MCA}
  - 100 KCAS came from C-2A Increased Gross Weight testing of 1988
  - 100 KCAS transposed to 100 KIAS
  - Report data showed at 100 KCAS additional rudder control power was still available

V_{MCA} - Scope of Tests



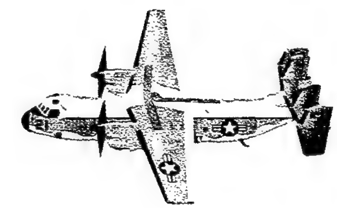
- Conditions
  - WO(20) - gear down, flaps 20 deg
  - WO(30) - gear down, flaps 30 deg
  - Power - defined by test technique
  - Altitude - 4000 ft
- 10 flights, 23 hours, V_{MCA} Static and Dynamic
- Test techniques used
  - Classic (method used to obtain previous V_{MCA})
  - Waveoff (method used in E-2C PLUS tests, considered more mission representative, yielded results herein)

Classic Technique



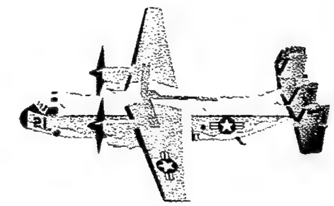
- Stabilize in climb at target airspeed with max power (4600 ISHP/engine)
- At target altitude copilot fails desired engine by rapidly pulling Condition Lever to FX (simulated - power lever to Flight Idle)
- No inputs for 1 second (except longitudinal inputs to control airspeed loss if desired)
- Apply recovery inputs as required

Classic Technique: Pros and Cons



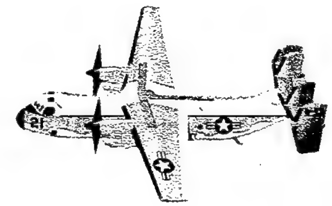
- Pros
  - Repeatable
  - Stable conditions at maximum power
- Cons
  - Nose high attitude
  - Not mission representative
  - Airspeed control following engine failure
    - Large airspeed loss
    - Large longitudinal push-over required to minimize airspeed loss

Waveoff Technique



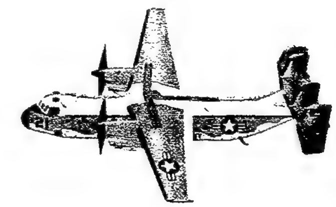
- Establish 500 FPM ROD (simulated approach)
- At target airspeed and altitude, rapidly advance power levers to max
- On power addition, copilot immediately fails desired engine by pulling Condition Lever to FX (simulated - power lever to Flight Idle)
- No inputs for 1 second (except small longitudinal inputs to control airspeed gain)
- Apply recovery inputs as required

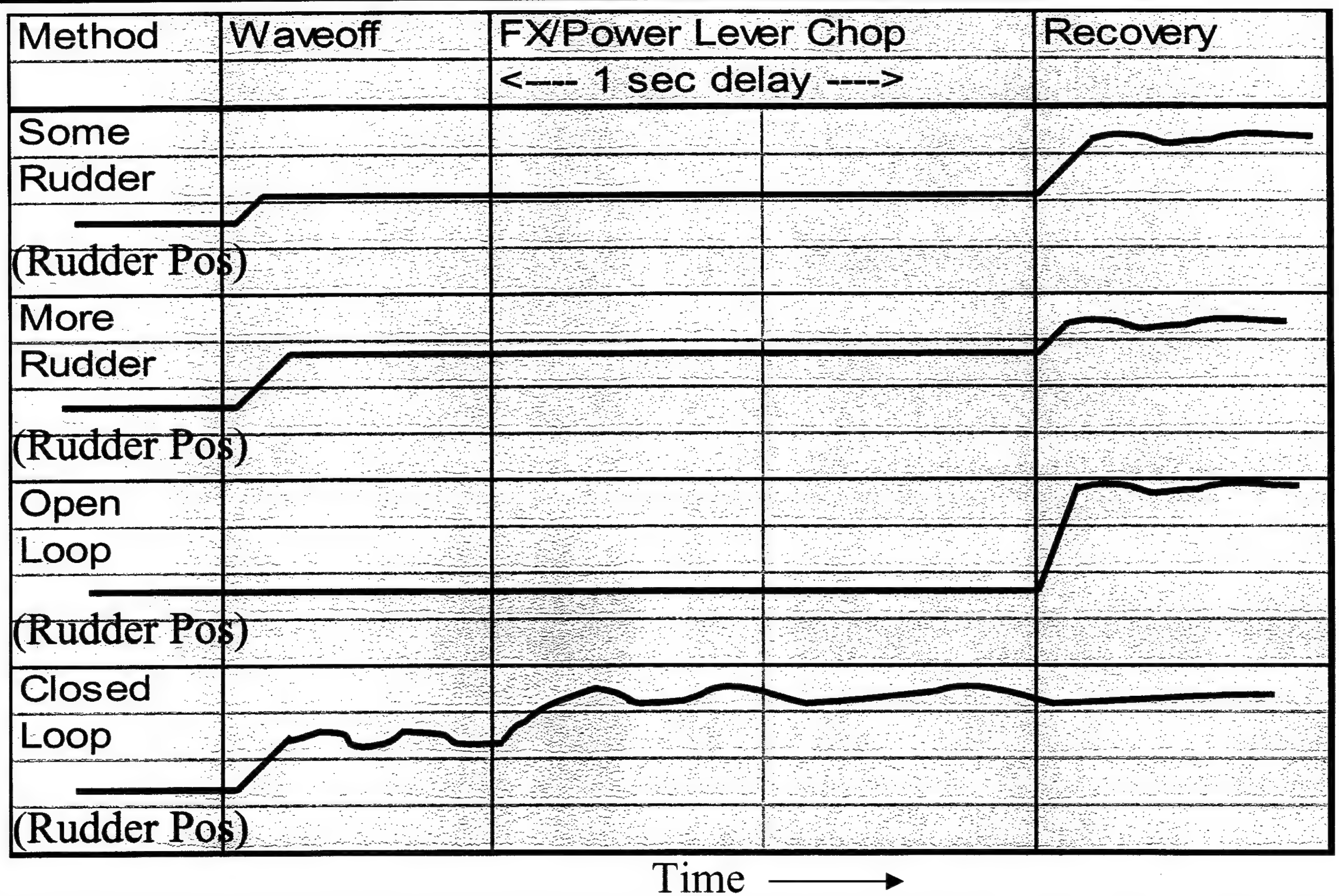
Waveoff Technique: Pros and Cons



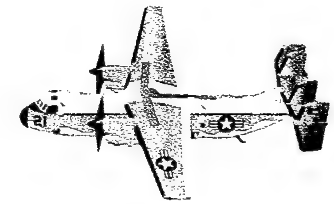
- Pros
  - Very mission representative (engine failure on waveoff)
  - Better airspeed control than Classic following engine failure
- Cons
  - Airspeed control following engine failure
    - Acceleration during power addition
  - Dynamic engine response with power addition
  - There can be non-repeatable control inputs on waveoff and recovery

Waveoff Technique Adjustments



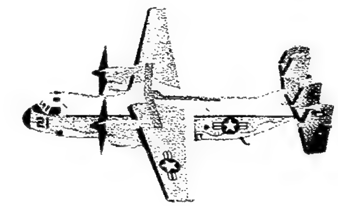


Waveoff Technique: Built-In Conservatism



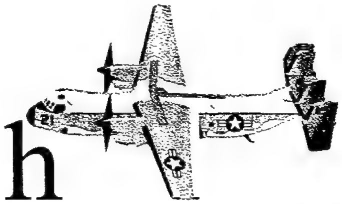
- Very rapid power addition
  - Power for Glide Slope to max power in ~0.2 seconds
  - Mechanical Power Lever Stop - adjustable for test day conditions. Allowed rapid power addition while preventing engine over-torque or over-temp
- Minimized airspeed acceleration
  - Simultaneously failed target engine while adding power on other
  - Permitted nose to rise slightly on power addition

Waveoff Technique: Built-In Conservatism (2)



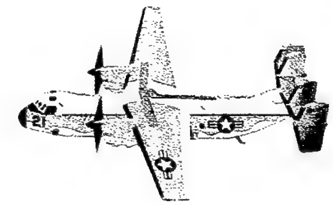
- Aft CG
- 1 second delay from engine failure to initial recovery inputs
- Different test pilot used for end points

Waveoff Technique: Another Possible Approach

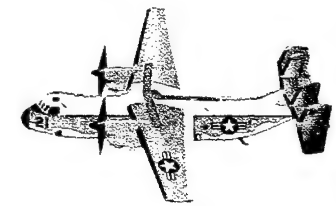


- Stabilize on target airspeed with 1/2 max power on each engine
- Concurrently -
  - FX target engine
  - Add Max power on other engine
- Recovery inputs after 1-2 second delay
- Technique may minimize airspeed change on engine failure
  - Net change of 0 thrust
- Not tested here

V_{MCA} Criteria:

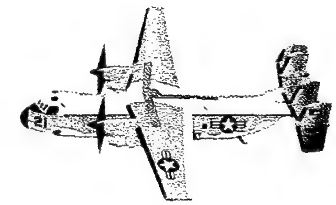


- Angular acceleration fails to reverse immediately at control input
- Time from initiation of rudder input to 0 yaw rate is greater than 2 sec
- 23 ½ units AOA (artificial stall warning)
- > 15 deg sideslip



V_{MCA} Criteria (2):

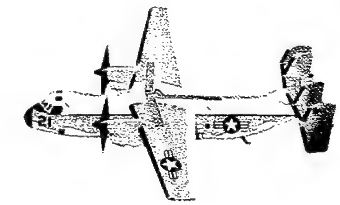
- > 20 deg bank angle
- > 20 deg heading change
- Static single engine control airspeed
- Recovery is unsafe or required excessive workload for the average pilot

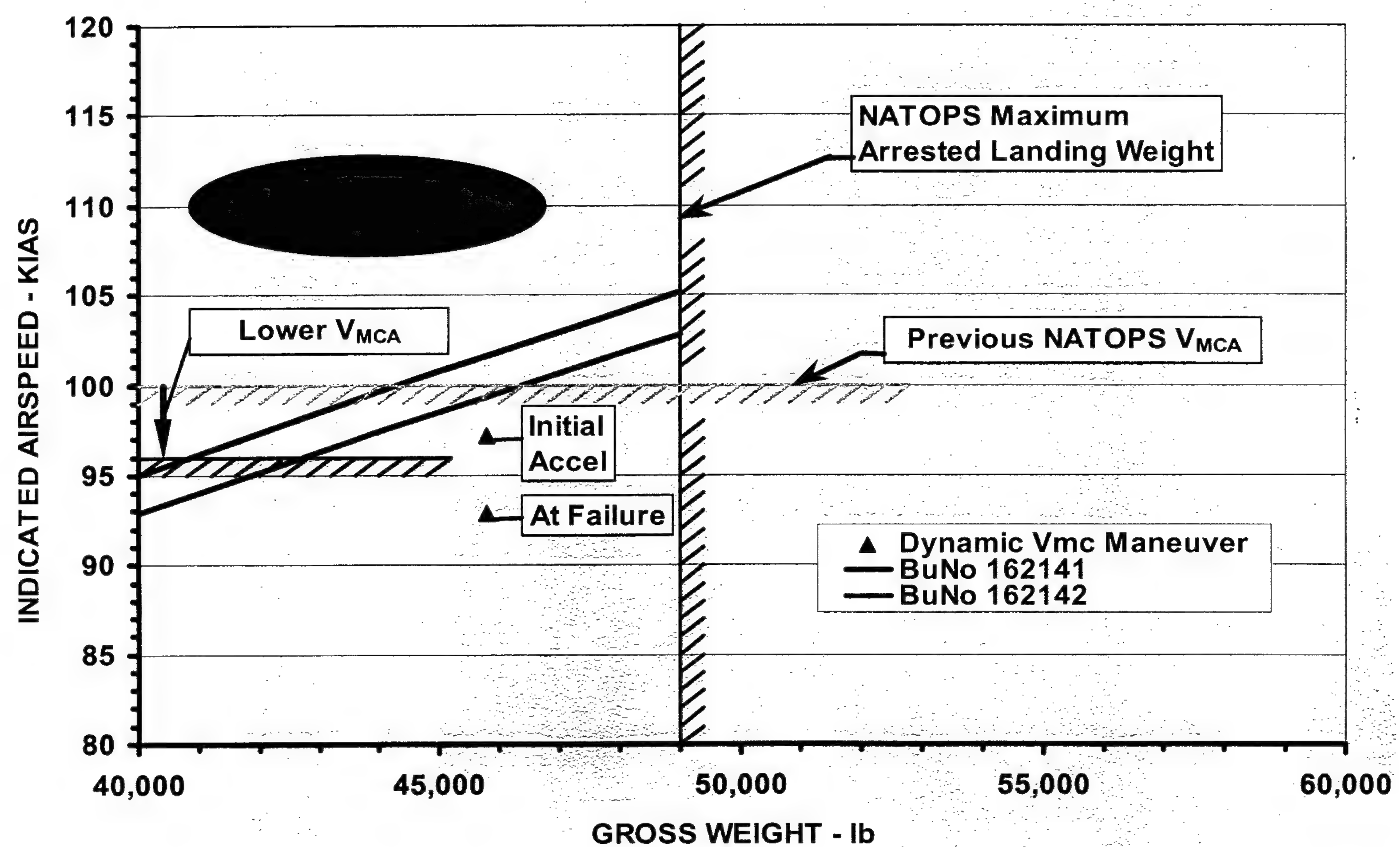


Results

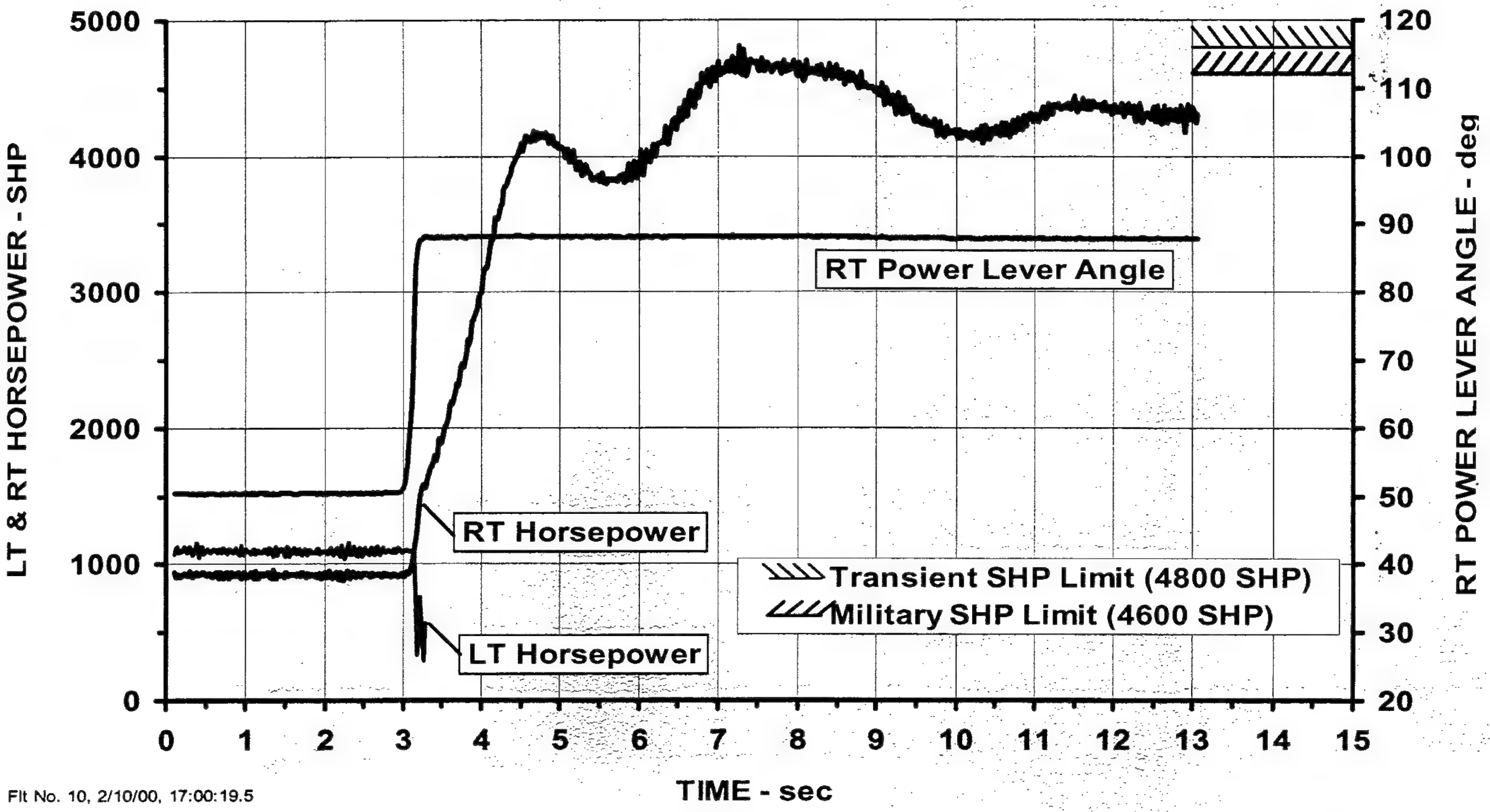
- Left engine was determined to be critical from previous testing and V_{MC} Static
- Results indicate a lower V_{MCA} than previously reported
  - V_{MCA} flaps 20 - 95 KIAS (excessive workload)
  - V_{MCA} flaps 30 - 96 KIAS (V_{MC} Static)
- Although controllable above V_{MCA}, adequate SERC performance is not assured

Dynamic Vmc Results, 20 Flaps





Engine Response



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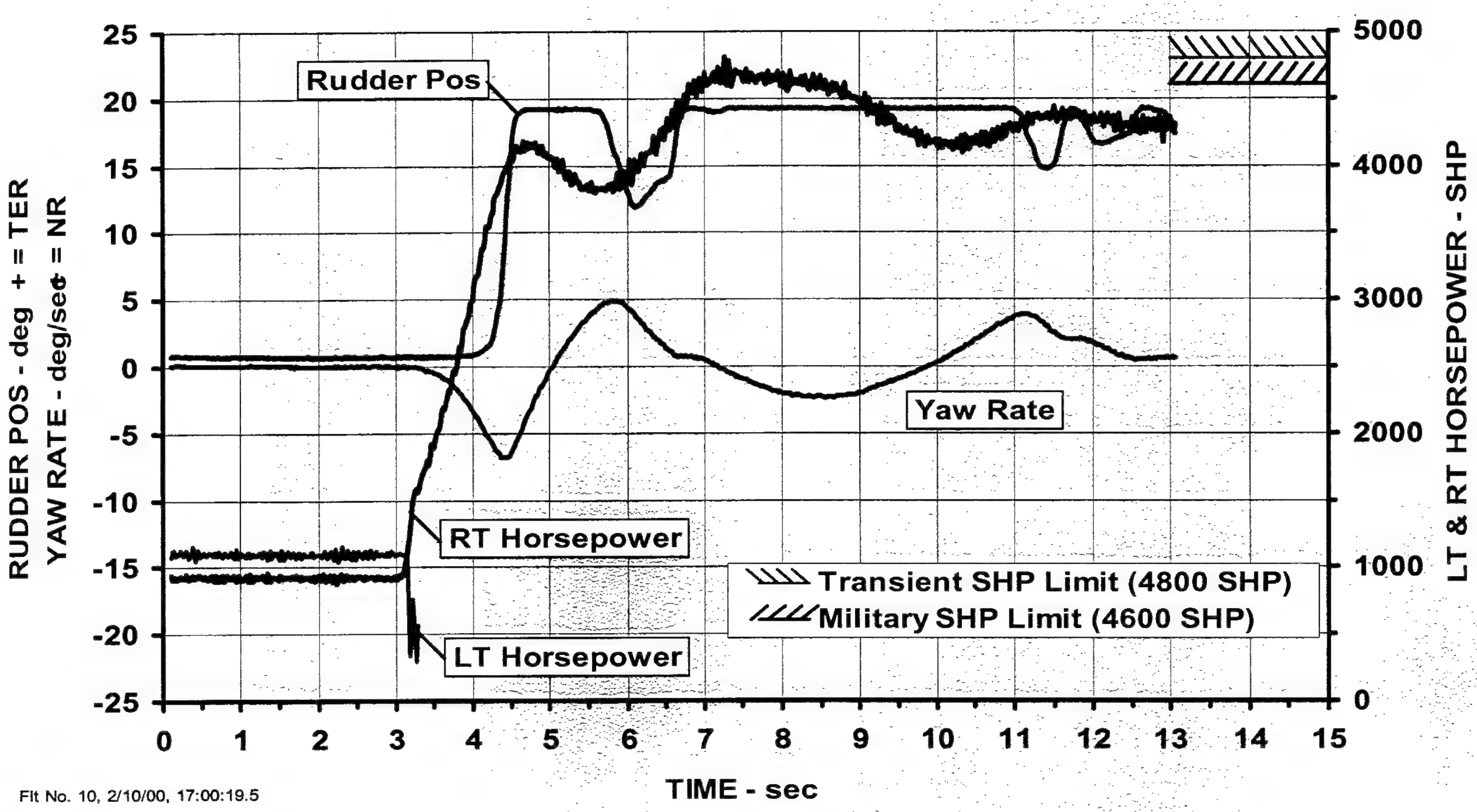
Force Aircraft Test Squadron

Recovery



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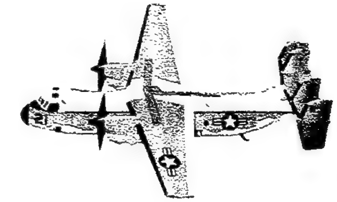
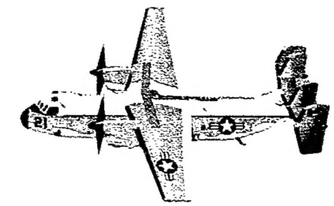
Recommendations



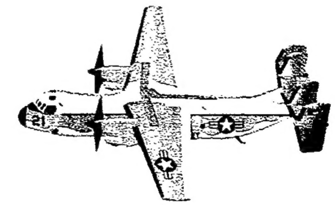
- C-2A NATOPS changes
  - New V_{MCA}
  - “Engine Failure During Waveoff” - descriptive paragraph not previously incorporated

Lessons Learned



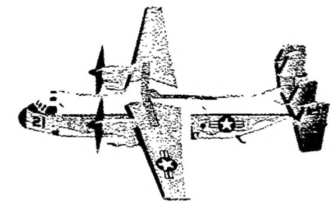
- Test Planning:
  - Consider normal dual-engine waveoff control input profiles and assess their impact on control inputs during V_{MCA} tests
  - Consider different methods of securing engine/ FX prop (Auto FX, Condition Lever, T-handle)

Lessons Learned (2)

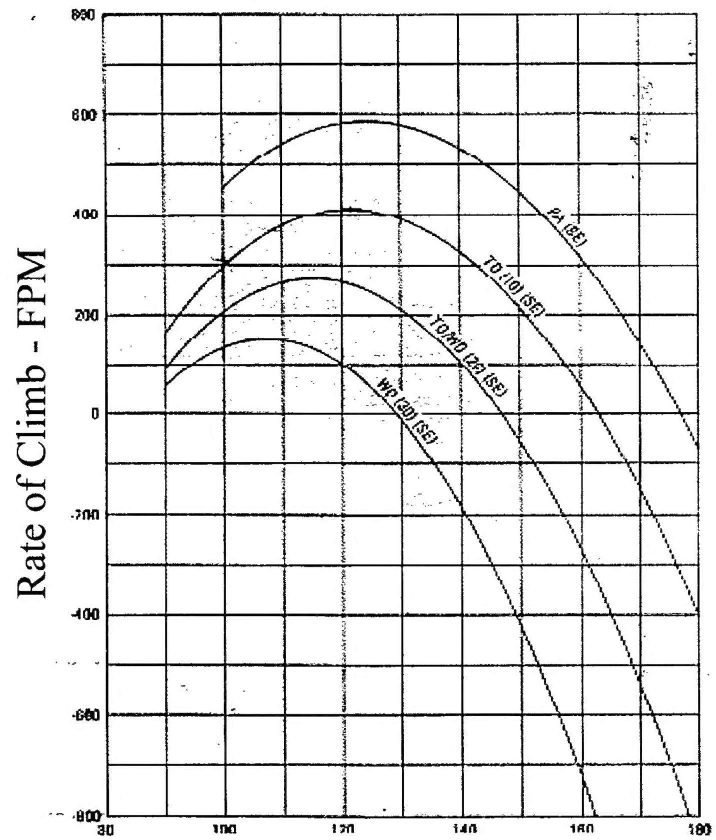


- Testing:
  - Minimize airspeed change from engine failure to recovery inputs.
  - Consider impact of airspeed changes in data reduction.
  - Waveoff technique - Operating engine may not be at maximum power when making recovery inputs (depends on engine response)

Lessons Learned (3)



- V_{MCA} Ramification
  - Adequate single engine performance may not be assured at V_{MCA}
    - Example: Rate of climb



SINGLE-ENGINE CLIMB PERFORMANCE
Reprocured C-2A Airplane, BuNo 162140

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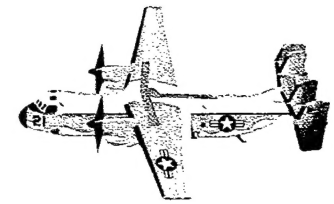

?? Questions ??